Boundary Scattering in Ballistic Graphene

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Charge carrier scattering at sample boundaries, boundary scattering, is a key element for understanding transport properties of graphene devices. To study boundary scattering effect, the charge carrier mean free path l_{mfp} has to be larger than the sample size. In this work, we report on the observation of anomalous magnetoresistance peaks due to diffusive charge carrier scattering at sample boundaries in ballistic graphene mesoscopic wires [1]. The magnetoresistance peak field scaled with the ratio of cyclotron radius R_c and wire width W as $W/R_c \sim 0.9$, different from that of classical semiconductor two-dimensional electron system $W/R_c \sim 0.55$.

We fabricated graphene/boron nitride mesoscopic wire devices using the mechanical transfer technique of monolayer graphene on hexagonal boron nitride substrate [Fig. 1 (a)]. The fabricated device exhibited high mobility $\mu \sim 70{,}000$ cm^2/Vs at $T = 4$ K. The mean free path of charge carriers reached ~1 μm at high charge carrier density $n \sim 3\text{x}10^{12}$ cm^{-2}. In magnetoresistance curves, we observed anomalous peak structures at magnetic fields B_{max} [colored region in Fig. 1 (b)]. The value of B_{max} scaled with the ratio of cyclotron radius R_c and sample width W as $W/R_c \sim 0.9$, indicating the magnetic commensurability effect between R_c and W. These observations indicate that the trajectories of charge carriers are bent by cyclotron motion and are scattered diffusively at the sample boundaries [inset in Fig. 1]. The proportionality constant between W and R_c differed from the case of conventional semiconductor two-dimensional electron system where $W/R_c \sim 0.55$ [1]. This observation suggests that the standard relation between R_c and W in semiconductor two-dimensional electron systems [2] has to be modified to explain the observed transport phenomena in graphene. Moreover, when the temperature was increased, the anomalous curves were retained up to room temperature. The temperature-dependent studies of resistivity indicate that the suppression of extrinsic charge carrier scatterings (optical phonon and impurities) compared to the conventional graphene on SiO_2 was the origin of the robust ballistic transport in graphene on hexagonal boron nitride.

[1] S. Masubuchi *et al.*, Phys. Rev. Lett. **109**, 036601 (2012).

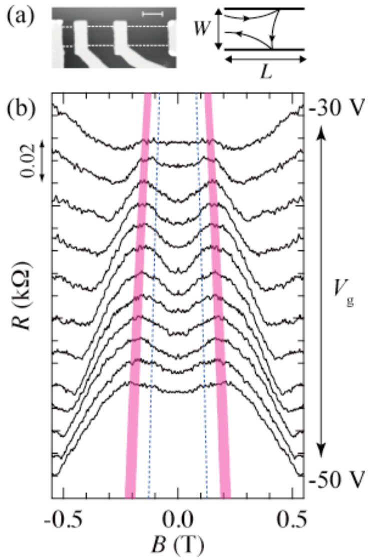

FIG. 1: (a) Atomic force microscopy image of the sample studied (b) Magnetoresistance curves at $T = 4$ K for gate-bias voltage $V_g = -30$, -32, ..., and -50 V (top to bottom). The blue dotted curves and colored area indicate the expected peak positions for W/R_c = 0.55 and 0.9 ± 0.1, respectively.